PREPARATION OF RICE FLOUR BASED FRENCH FRY USING TWIN-SCREW EXTRUSION

Hathairat Pinkaew[1*]

Abstract

The objective of this study was to develop rice flour based French fry product. The dry-milled non-glutinous rice flour from three Thai rice cultivars such as Chai Nat1 (CN1), Khao Ta Heang (KTH) and Khao Dawk Mali 105 (KDML105) was premixed with dry-milled glutinous rice flour (Rice Division6, RD6) at two different ratios 40:60 and 20:80 (w/w). The rice flour based French fry formulations were processed using a co-rotating twin-screw extruder up to 70°C. The 30 cm long, extruded rice flour based French fry samples were cooled at room temperature (RT, 28°C) for 15 min and then cut into 7 cm. The extruded rice flour based French fry samples were prefried in rice bran oil at 170°C for 20 s, stored at -18°C for 1 week and then refried at 170°C for 20 s. Fundamental analyses of all flours found that swelling power and solubility were likely to increase while temperature increasing from 55 to 85°C and chemical compositions (moisture, crude fat, crude protein and amylose contents) were significant different ($p<0.05$). The microbial quality of extruded rice flour based French fry samples were in the safety level and the statistical analyses showed the interaction between rice varieties and flour ratios on qualities of extruded rice flour based French fry samples either before or after frying ($p<0.05$). Furthermore, the hardness of samples was related to the swelling power and amylose content. The lowest hardness and oil absorption was provided by KTH: RD6 in the ratio of 40:60.

Keywords : Rice flour, French fry, Extrusion

[1] *Food Technology Program Kranuan School Suan Dusit University*

[*] *Corresponding author e-mail: hathairat_pin@dusit.ac.th, phathairut@hotmail.com*

Introduction

A typical procedure for producing "home-style" French fries in a foodservice includes cutting whole potatoes (peeled or unpeeled) into approximately 0.95 cm square and 10 cm long strips, or other sizes (e.g., large "steak fry" strips), and oil blanching the strips at approximately 177°C for 4 min. The potato strips are held at about 20 to 27°C on sheet pans or in plastic food storage tubs for up to 8 h prior to finish frying for 3 to 3.5 min at approximately 182 to 188°C. During holding, there is potential for contamination from humans and contact surfaces. Contamination of blanched potato strips by foodborne pathogens could cause hazardous situations (Doan and Davidson, 1999).

French fries are among the major commercial fried foods and accounted for 44% of processed potatoes in the US. The globally expanding quick-serve restaurants (QSRs) are common places for consumption of French fries. In the most popular QSRs, a large serving of French fries could contain 519 ± 30 calories, where 45.5 ± 1.7% calories come from fat. It has been evidenced by many epidemiological studies that the consumption of oil-rich foods causes obesity and development of many cardiovascular diseases. Therefore, due to increased health awareness, the quality of food is judged by the consumers not only on the basis of color, odor, and taste, but also on the fat content (Bingol *et al*., 2012). Previous work showed that even potatoes and rice have very similar proximate compositions, potato-based French fries are considered to have higher oil absorption and fat content than those of rice-base fried products (Kadan, *et al*., 1997; Kadan, Bryant and Boykin, 2001).

Rice (*Oryza sativa* L.) is considered as a main staple food, not only for the population of Asia, but also the populations of other countries over the world. It is a major energy source being consumed daily. There are a number of rice varieties grown in Thailand. Rice types, based on amylose content varying from 0-35%, can be classified into 4 groups; waxy, low amylose, moderate amylose and high amylose rice. Each varies in its chemical compositions, properties and qualities (Moongngarm, 2013). Many studies have shown that the constituents in the flour affect the characteristics of starch-based products. Moisture, protein, amylose and amylopectin contents were found to correlate with the expansion, oil absorption and crunchiness of fried crackers (Mohamed and Hamid, 1994). Moreover, the flour constituents also affected to extrusion characteristics of starch-based products and expansion characteristics of extruded products. Mohamed and Hamid (1994) also reported that the physical characteristics such as expansion, oil absorption and crispiness of fried rice dough from flour mixture containing rice: glutinous rice in the ratio of 75:25 was affected by the amylose/amylopectin content. The volume expansion and oil absorption of the finished products were found to be directly proportional to the amylopectin content and inversely proportional to the amylose content of the flour. Therefore, this study was designed to evaluate the effects of rice cultivars with different amylose contents (high, moderate and low) and different ratios of rice flour mixtures between non-glutinous and glutinous rice, would have on the moisture, oil absorption, and texture of an extruded rice flour based French fry product.

Materials and Methods

Materials

Three non-glutinous Thai rice cultivars (*Oryza sativa* L.): Chai Nat1 (CN1, high amylose), Khao Ta Heang (KTH, moderate amylose) and Khao Dawk Mali105 (KDML105, low amylose) and one glutinous rice cultivar (Rice Division6, RD6) were obtained from the Rice Research Center (Bangkok, Thailand). Polished rice samples were dry-milled then passed through a 100-mesh sieve, packed in plastic bags, and stored at –18°C before further use. Analytical-grade chemicals were used in this research unless otherwise noted.

Swelling power and water soluble Index

Swelling power (SP) was determined using 0.1 g of rice flour by the modified method of Tsai, Li and Lii (1997). Rice flour was weighed into glass tubes with coated screw caps to which 10 mL of distilled water was added. The tubes were placed in a shaking water bath at 55, 65, 75 and 85°C for 10 min and transferred into a

boiling water bath. After boiling for 1 h, the tubes were cooled in cold water for 5 min and centrifuged at 8,000 ×g for 20 min. The supernatant was carefully removed and then dried in hot air oven at 100°C. The water soluble index (WSI) was calculated from dried supernatant and SP was determined as sediment weight (g/g).

Chemical composition

The moisture content was measured by air-oven methods according to Approved 149 Method 44-15A (AACC, 2000). Crude fat was measured according to Approved Method 30-20 (AACC, 2000) using a Soxtec apparatus and hexane as the solvent. Crude protein was measured by a Kjeldahl method according to Approved Method 46-11A (AACC, 2000) using the conversion factor of 5.95 to convert nitrogen content to crude protein. Crude fiber was measured according to Approved Method 32-10 (AACC, 2000) using Fibertec apparatus. The apparent amylose content (AAC) was measured using the colorimetric method of Juliano (1971). All chemical compositions were measured in duplicate.

Extrusion of rice flour based French fry

The extruded rice flour based French fry was produced following the method of Kadan, Bryant and Boykin (2001) with slightly modified. The non-glutinous rice flour was mixed with glutinous rice flour at two different ratios (60:40 and 80:20). Rice flour mixed (92.3%) was then combined with defatted rice bran (2.7%) salt (2.7%) and sugar (2.3%). Each formulation was extruded using a co-rotating and intermeshing twin screw extruder (Model APV Baker MPF 19.25, England). The die was fixed at 6 mm diameter circular holes and extrusion temperature at 70°C. The 30 cm long, extruded rice flour based French fry samples were cooled at room temperature (RT, 28°C) for 15 min and then cut into 7 cm. The extruded rice flour based French fry samples were prefried in rice bran oil at 170°C for 20 s, cooled at RT, packed in plastic bag and stored at –18°C before further analyses.

Experimental design

A 3×2 full factorial in complete randomized design (CRD) was employed to investigate the influence of three rice cultivars (CN1, KTH, and KDML105) and rice flour mixed ratios (40:60 and 20:80) on the physical properties (texture) and chemical properties (moisture content and oil absorption) of extruded samples. Each treatment combination had three replicates.

Physical analysis

The texture of extruded rice flour based French fry before and after refried in rice bran oil at 170°C for 70 s were measured using texture analyzer TA XT2i (Stable Micro Systems, Surrey, England), with a Warner–Bratzler shear cell (1-mm thick blade) (Ilo, Liu, and Berghofer, 1999; Onwulata, *et al*., 2001). The samples were analyzed at a cross head speed of 0.2 mm/s. Single sample was placed across the Warner–Bratzler shear cell and cut into two pieces by the shear blade. The reported values were the average of 10 determinations.

Moisture content and oil absorption

The moisture content of extruded rice flour based French fry before and after refried were determined in triplicate by air-oven methods according to Approved 149 Method 44-15A (AACC, 2000). The oil absorption (oil content) of refried samples was investigated according to Approved Method 30-20 (AACC, 2000)

Microbiological Analysis

Microbiological testing of extruded rice flour based French fry was performed on 25-g samples from each treatment using the total plate count method on plate count agar. The colony-forming units were counted after incubation under aerobic conditions at 35°C for 48 h (Mukprasirt *et al*., 2001).

Statistical analysis

The SPSS for Windows program (SPSS 19.0) was employed to analyze the results. Data were subjected to analysis of variance (ANOVA). The differences among means were identified by Duncan's multiple-range test (DMRT) at significant differences of $p<0.05$.

Results and Discussion

Swelling power and water soluble Index

The swelling power (SP) and water soluble index (WSI) curves of 4 rice flour samples over the range 55–85°C are shown in Figure 1a and 1b. It was found that SP and WSI of all rice flour samples were increased while increasing temperatures ($p<0.05$). The glutinous or waxy rice flour (RD6) showed the highest SP and WSI when compared to three non-glutinous rice flour samples. Vandeputte *et al.* (2003) revealed that at temperatures between 55 and 85°C; waxy rice starch from waxy rice flour had higher SP than normal or non-glutinous rice starches. The researchers also reported that the SP of the latter was independent of amylose content. These results imply that amylose does not have a substantial impact on SP of the rice starch granules during 55 and 85°C.

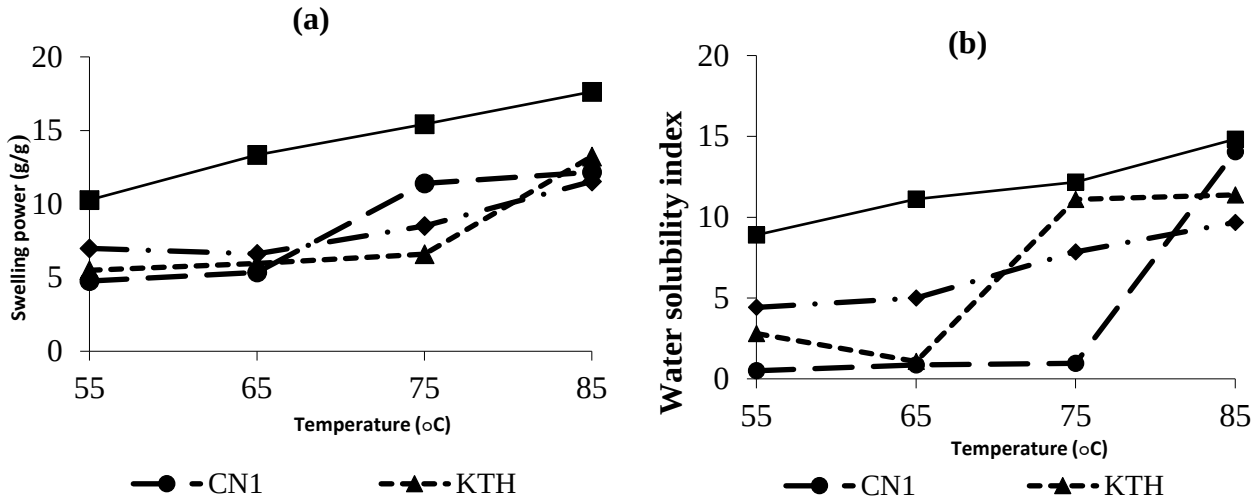

Figure 1 Swelling power (SP) (a) and water solubility index (WSI) (b) as a function of temperature for non-glutinous rice cultivars (CN1 = Chai Nat1, KTH = Khao Ta Heang (KTH), KDML105 = Khao Dawk Mali105), and glutinous rice cultivar (RD6 = Rice Division6)

Chemical composition

Chemical compositions are shown in Table 1. The moisture contents of all rice flour samples were in the ranged of 11.13-11.84%. The crude fat contents of all three non-glutinous rice flour samples (2.14–2.57%) were not significant different ($p>0.05$) but higher than that of waxy rice flour (1.33%). These results are in agreement with previous work in which the rice cultivars and types also affected crude fat content. The milled rice of low amylose rice Khao Dawk Mali105 (KDML105) had the lowest amount (1.46%), whereas the crude fat content of RD6 (waxy rice) and Khao Ta Heang (KTH, moderate amylose) varied from 1.79% to 1.85% (Moongngarm, 2013). The crude protein contents differed from 5.16 to 5.96%, showing the highest value in high amylose rice (Chai Nat1, CN1), whereas the crude fiber of all rice flour samples were not significant different ($p>0.05$). The apparent amylose content was low in the RD6 rice flour (0.81%), while KDML105 and KTH contained low and moderate concentrations (18.77 and 25.31% respectively). The highest level of amylose was found in CN1 rice flour (28.63%).

Table 1 Chemical composition of rice flour[a]

Rice cultivar	Moisture content (%)	Chemical composition (%dry basis, db)			
		Crude fat	Crude protein	Crude fiber[ns]	Amylose content
CN1	11.58a±0.18	2.57a±0.25	5.96a±0.12	0.50±0.14	28.63a±1.04
KTH	11.13b±0.11	2.30a±0.38	5.21c±0.12	0.69±0.22	25.31b±1.09
KDML105	11.25b±0.21	2.14a±0.54	5.59b±0.14	0.80±0.06	18.77c±0.68
RD6	11.84a±0.17	1.33b±0.04	5.16c±0.12	0.56±0.19	0.81d± 1.04

Note – [a]Means value ± SD with different small letters in the same column are significantly different ($p<0.05$), ns = not significantly different ($p>0.05$)

– CN1 = Chai Nat1, KTH = Khao Ta Heang (KTH),
KDML105 = Khao Dawk Mali105, RD6 = Rice Division6

Extruded rice flour based French fry properties

The properties of extruded rice flour based French fry are shown in Table 2. The texture property and moisture content of extruded rice flour based French fry were significantly ($p<0.05$) influenced by the extrusion process, and there was a significant ($p<0.05$) interaction between rice cultivars and rice flour mixed ratios. After all the rice flour were mixed and then extruded, the extruded rice flour based French fry from KDML105 had the highest hardness, this was related to the lowest SP at high temperature (85°C) as shown in Figure 1a.

The moisture content of extruded rice flour based French fry also affected by the rice cultivars and rice four mixed ratios ($p<0.05$). It was found that the extruded rice flour based French fry from CN1 at 20:80 rice flour mixed ratio and extruded rice flour based French fry from KDML105 in which 40:60 rice flour mixed ratio showed the highest moisture contents due to the high moisture content of both rice flour as shown in Table 1.

The microbiological testing results showed that the total plate count of all extruded rice flour based French fry samples were in the ranged 4.6×10^2 to 7.1×10^2 CFU/g which is not excess the standard limit for French fry (1×10^3 CFU/g) (Thai Community Product standard, 110–2546).

Table 2 Properties of extruded rice flour based French fry[a]

Rice cultivar	Ratio of rice flour (non-glutinous: glutinous)	Properties		
		Hardness (N)	Moisture content (%)	Total plate count (CFU/g)
CN1	40:60	663.87b± 104.27	10.67b± 0.18	6.5×10^2
	20:80	626.54c± 68.07	11.25a± 0.32	6.3×10^2
KTH	40:60	530.92d± 87.22	10.10c± 0.17	4.6×10^2
	20:80	548.35d± 74.44	10.64bc± 0.13	6.5×10^2
KDML105	40:60	740.55a± 83.43	11.61a± 0.55	7.1×10^2
	20:80	732.97a± 86.52	10.28bc± 0.08	6.3×10^2

Note – [a]Means value ± SD with different small letters in the same column are significantly different ($p<0.05$)
– CN1 = Chai Nat1, KTH = Khao Ta Heang (KTH),
KDML105 = Khao Dawk Mali105, RD6 = Rice Division6

Refried extruded rice flour based French fry properties

The refried extruded rice flour based French fry samples from various rice cultivars had differed apparent and color as shown in Figure 2.

Rice cultivar	Ratio of rice flour (non-glutinous: glutinous)	
	40:60	20:80
CN1		
KTH		
KDML105		

Figure 2 Refried extruded rice flour based French fry samples from three Thai non-glutinous rice cultivars (CN1 = Chai Nat1, KTH = Khao Ta Heang (KTH), KDML105 = Khao Dawk Mali105), and glutinous rice cultivar (RD6 = Rice Division6)

It was found that the rice cultivars affected on the color whereas the RD6 content on the rice flour mixed ratio affected to the expansion of all refried extruded rice flour based French fry samples (Table 3).

Table 3 Properties of refried extruded rice flour based French fry[a]

Rice cultivar	Ratio of rice flour (non-glutinous: glutinous)	Properties		
		Hardness (N)	Moisture content (%)	Oil absorption (%)
CN1	40:60	191.34b± 57.87	13.93e± 0.07	0.05a± 0.01
	20:80	163.69c± 43.48	14.43b± 0.11	0.04b± 0.00
KTH	40:60	146.27d± 25.78	13.54 f ± 0.02	0.04b± 0.01
	20:80	178.61bc± 29.73	14.11d± 0.01	0.06a± 0.01
KDML105	40:60	269.05a± 54.44	15.28a± 0.01	0.03c± 0.00
	20:80	192.30b± 25.99	14.35c± 0.01	0.03c± 0.00

Note – [a]Means value ± SD with different small letters in the same column are significantly different ($p<0.05$)
– CN1 = Chai Nat1, KTH = Khao Ta Heang (KTH),
KDML105 = Khao Dawk Mali105, RD6 = Rice Division6

The sample which contained 40% CN1 (high amylose rice) and 60% RD6 (waxy rice) had the yellowish color and less rough surface. However, increased the RD6 content in the formula was trend to increase the expansion rate and roughness of samples surface. These results were related to the high SP of RD6 due to its high amylopectin content. The sample which contained KDML105 (low amylose rice) also provide the yellowish color whereas the KTH (moderate amylose rice) showed the brownish color. Many researches revealed that rice cultivars and amylose content affected to the expansion rate of rice snacks either extrude or non-extrude process (Rani and Bhattacharya, 1989; Keeratipibul, Luangsakul, and Lertsatchayarn, 2008; Nipornram, Srapinkornburee and Tassanaudom, 2012). Furthermore, Keeratipibul, Luangsakul, and Lertsatchayarn, (2008) also reported that in order to obtain good qualities of rice cracker, the rice should have lower amylose content, softer cool paste texture, greater breakdown value and less setback of amylogram. These results are in agreement with Nipornram, Srapinkornburee and Tassanaudom (2012) who found that different rice cultivars and quantities of black glutinous rice had effects on hardness and expansion of rice cracker. The rice cracker which contained 20% of black glutinous Omkoi (apparent amylose content, AAC 9.00%) rice cultivar performed the best quality when compared to black glutinous Doisaket (AAC 9.70%) rice cultivar. Researchers explained that black glutinous Doisaket rice cultivar had higher amylose content than those of Omkoi and thus provided harder texture.

The moisture contents of refried extruded rice flour based French fry samples from various rice cultivars are in the ranged of 13.54–15.28%. All samples showed low oil absorption, which mean low amount of oil that absorbed into the products (0.03–0.06%). Moreover, all samples which contained CN1 and KTH rice flour provided higher oil absorption that those of KDML105 due to their higher expansion and more rough surfaces.

Conclusions

The swelling power and water soluble index of all rice flour depended on rice cultivars. The glutinous rice (Rice Division6, RD6) showed higher swelling power and water soluble index than those of non-glutinous rice flour and affected the expansion, hardness and oil absorption of extruded rice flour based French fry produced from mixed non-glutinous and glutinous rice flour. The rice flour based French fry could produce from mixed rice flour between moderated amylose rice flour and glutinous rice flour in the ratio of 40:60 using extrusion process. However, these extruded rice flour based French fry still had undesirable appearance and some sticky characteristics during mastication when compared to the potato based French fry. Other rice cultivars and ratios between non-glutinous rice and glutinous rice flour should be explored to further improve the properties of extruded rice flour based products.

Acknowledgment

This research was supported by grants from Suan Dusit University, Bangkok, Thailand.

References

AACC. (2000). **Approved Methods of the American Association of Cereal Chemists, American Association of Cereal Chemists**. 10th ed. St. Paul, Minnesota, USA.

Bingol, G., Zhang, A., Pan Z. and Mchugh, T. (2012). Producing lower-calorie deep fat fried French fries using infrared dry-blanching as pretreatment. **Food Chemistry**. 132(2): 686–692.

Doan, C.H. and Davidson, P.M. (1999). Growth of *Bacillus cereus* on oil-blanched potato strips for "Home-style" French fries. **Journal of Food Science**. 64(5): 909–912.

Ilo, S., Liu, Y. and Berghofer, E. (1999). Extrusion cooking of rice flour and amaranth blends. **Lebensmittel-Wissenschaft und-Technologie**. 32: 79–88.

Juliano, B.O. (1971). A simplified assay for milled-rice amylose. **Cereal Science**. Today 16: 334.

Kadan, R.S., Champagne, E.T., Ziegler, G.M. and Richard, O.A. (1997). Amylose and protein contents of rice cultivars as related to texture of rice-based fries. **Journal of Food Science**. 62(4): 701–703.

Kadan, R.S., Bryant, R.J. and Boykin, D.L. (2001). Effects of processing conditions on qualities of rice fries. **Journal of Food Science**. 66(4): 610–613.

Keeratipibul, S., Luangsakul, N. and Lertsatchayarn, T. (2008). The effect of Thai glutinous rice cultivars, grain length and cultivating locations on the quality of rice cracker (Arare). **Food Science and Technology**. 41(10): 1934–1943.

Mohamed, S. and Hamid, N.A. (1994). Effects of various food components on the expansion, oil absorption, and crispiness of fried rice dough. **Pertanika Journal of Tropical Agricultural Science**. 17(1): 7–12.

Moongngarm, A. (2013). Chemical compositions and resistant starch content in starchy foods. **American Journal of Agricultural and Biological Sciences**. 8(2): 107–113.

Mukprasirt, A., Herald, T.J., Boyle D.L. and Boyle, A.E. (2001). Physicochemical and microbiological properties of selected rice flour-based batters for fried chicken drumsticks. **Poultry Science**. 80: 988–996.

Nipornram, S., Srapinkornburee, V. and Tassanaudom, A. (2012). Effects of cultivars and quantity of black glutinous rice on the quality characteristics of rice cracker. **Khon Kaen University Science Journal**. 40(3): 890–898.

Onwulata, C.I., Konstance R.P., Smith, P.W. and Holsinger, V.H. (2001). **Lebensmittel-Wissenschaft und-Technologie**. 34: 424–429.

Rani, S.M.R. and Bhattacharya, K.R. (1989). Rheology of rice flour paste: effect of variety, concentration, and temperature and time of cooking. **Journal of Texture Studies**. 20: 127–137.

Thai Community Product standard. (2546). **Fried potato** (110–2546). Thai Industrial Standards Institute (TISI).

Tsai, M.L., Li, C.F. and Lii, C.Y. (1997). Effects of granular structures on the pasting behaviors of starch. **Cereal Chemistry**. 74(6): 750–757.

Vandeputte, G.E., Derycke, V., Geeroms, J. and Delcour, J.A. (2003). Rice starches. II. Structural aspects provide insight into swelling and pasting properties. **Journal of Cereal Science**. 38: 53–59.